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From Artefacts to Infrastructures

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Abstract

In their initial articulation of the direction of the CSCW field scholars advanced – and continue to advance - an open-ended agenda. However, trawling through the major CSCW outlets, this is not what one finds in practice. Rather the field appears to privilege particular forms of cooperative work. These are studies of restricted and confined settings - or what might be termed more generally as localist studies of the 'here and now'. This focus is particularly problematic when one considers the kinds of large-scale, integrated and interconnected workplace information technologies – or what we are calling Information Infrastructures (II) – that can be found within and across organisations today. CSCW appears unable (or unwilling) to grapple with these technologies - which were at the outset envisaged as falling within the scope of the field. Our paper hopes to facilitate greater CSCW attention to Information Infrastructures through offering a re-conceptualisation of the role and nature of 'design'. In particular we focus on the two themes of 'standardisation' and 'heterogeneity' which we find to be present but largely unaccounted for in CSCW studies. We discuss these themes through introducing material from our own studies.

1. Introduction

Computer supported collaborative work (CSCW) was coined as a broadly conceived, interdisciplinary research stream (Greif 1988). As Schmidt and Bannon (1992, p. 13) wrote in the inaugural issue of the CSCW journal, "[a]t the core of this conception of cooperative work is the notion of *interdependence in work*" thus suggesting that this nascent field was not restricted in nature nor form.

In this paper we argue that despite its early and explicit recognition as an open-ended agenda for cooperative work, CSCW has de facto – as evident from its principal academic outlets, such as the CSCW journal, the CSCW and ECSCW conferences - privileged more restricted, confined and specialised forms of cooperative work. Thus two meanings of the field have emerged: *CSCW-in-use* consisting of dominant theoretical concepts, methodological approaches and empirical scope as mirrored in CSCW's principal outlets; and *espoused-CSCW* referring to the more open agenda initially accompanying CSCW. Our interest is in revitalising the agenda of espoused-CSCW as a more visible part of CSCW-in-use.

The aim of this paper is thus to move beyond a critique of dominant perspectives on CSCW to contribute by outlining an alternative perspective on CSCW we call *Information Infrastructures (II)*. The driving motivation behind our II perspective on CSCW is to theoretically, methodologically and empirically pursue the dependencies in time and space beyond the 'here and now' privileged by more traditional, work place oriented studies of CSCW.

Our critique has its roots in a number of fields allied to CSCW - Information Systems Research, Science and Technology Studies, Organisation Studies, and Social Informatics - which have begun to problematize overly 'localised' explanations of technology. Williams and Pollock (in press) have critiqued the preoccupation of information system researchers with the 'implementation study'. Karasti et al. (2010, p. 407) have described the bias towards 'short-term temporal aspects' of workplace information technologies. Kallinikos (2004) has cautioned against the study of information artefacts predominately (or only) at the place where the user encounters them.

The problem when we focus on one specific locale or moment is that we find that important influences from other levels and moments are ignored. Focusing on implementation and use, for instance, means that a whole range of important actors and factors are relegated to the background. This view is inherently problematic when one considers that the bulk of software used within organisations today is not developed in-house but at some distance from its place of use. This means that various dependencies in time and space – which will important consequences for the unfolding of a technology - will precede the adoption of this particular system. Existing studies within CSCW are not well equipped to consider the broader constraints and formatting associated with today's workplace information technologies. Local actions are sustained and constrained by an extensive network of technical, organisational and social arrangements whereby some (material, institutional) elements are difficult for local actors to change (Kallinikos 2004).

This suggests that the emphasis on single locales or specific moments is particularly inadequate for exploring the development and influence of present and emerging complex II, which, are typically shaped across multiple contexts and develop over extended periods of time. We contribute by identifying, illustrating and discussing important research *themes* for CSCW foregrounded by our II perspective and then go onto spell out some *implications* from our perspective, notably by outlining a re-conceptualisation of the role and nature of 'design' as related to CSCW. The notion of design we will put forward is one suitable for discussion of modern IIs and is thus distinctly more distributed and heterogeneous.

The remainder of the paper is organised as follows. Section two describes the work of those CSCW scholars that we regard as already aligned with/supporting the suggestions set out here. Sections three and four discusses two key themes – standardisation and heterogeneity – that we find to be relatively under analysed within CSCW so far and which we argue needs further discussion. We illustrate how these themes might be analysed through discussing our own recent empirical work. Section five revists the debate on how CSCW might inform design whilst section six concludes by arguing that CSCW should develop a more prospective outlook in order to adequately study new, emerging technologies.

2. Conceptualising Cooperative Work

There has from its inception been what some scholars have dubbed a 'localist' sensibility in CSCW (Pollock and Williams 2007). This sentiment is manifest in the CSCW emphasis on work place studies and single site-implementations (in a specific department or an organisation) (see for instance Fitzpatrick 2003), the influence of ethnographically inspired research methods (Rooksby et al. 2009), a focus on the adoption of a given system rather than how users collaborate using multiple systems (Berg 1999) and studies of relatively small numbers of users (hundreds rather thousands).

A telling illustration of CSCW's preoccupation with the local is the level of interest into the notion of and technologies supporting 'awareness' (see for example Gutwin and Greenberg 2002). The *Journal of Computer Supported Cooperative Work (JCSCW)*, for instance, has published 176 (!) papers addressing awareness (in the title and/or abstract) in its 20 volumes to date. The notion of awareness *is* about the micro-mechanics of collaboration and will necessarily privilege ethnographically inspired modes of empirical inquiry. There is accordingly a reciprocal relationship in CSCW between key theoretical constructs and methodological bias that are mutually reinforcing.

2.1 Design Studies and the Local Sensibility

It is clear than an important ambition of CSCW is directed towards improving the design of computer-based systems by acquiring a deeper understanding of the collective and collaborative character of work processes and how they may be better supported by more appropriately designed systems. This ambition has benefited greatly from the growing influence of localist perspectives (inspired, for example, by the exciting work of authors such as Lucy Suchman (1987)) and an associated enthusiasm for ethnographic studies, which has been very effective as a research methodology in producing rich pictures of particular design settings. However, in doing this kind of research, ethnographers have often opted for relatively restricted notions of the 'local setting' - mostly involving single site studies or studies of a number of closely-related settings (Marcus 1995). However the 'localist turn' within the social sciences has been criticised, most notably by Harris (1998, p. 295), who has argued that an overly confined notion of the 'local' or 'situation' is not useful:

> [w]hether one speaks of 'local', 'situated', or 'embedded' knowledge, the implication is that the narrative is somehow confined to a small 'space' – if not in the literal sense of a geographical metric, then at least in the sense of restricted social, cultural, and temporal metrics.

We are in accord with these sentiments but also note how they echo Schmidt and Bannon's (1992) early attempt to define an agenda for CSCW where they explicitly argued that CSCW should expand its empirical basis. They noted specifically how the prevailing notion of a 'group' confined the relevance of CSCW:

> It has - implicitly or explicitly - been the underlying assumption in most of the CSCW oriented research thus far that the cooperative work arrangement to be supported by a computer artifact is a small, stable, egalitarian, homogeneous, and harmonious ensemble of people - a 'group' (ibid., p. 15).

There are clearly a number of exceptions to the critique of the CSCW field offered by Schmidt and Bannon (discussed in the next section) but we would also argue that the thrust of their critique still remains largely valid today – some 20 years later. Too little has been done to flesh out this important and more expansive agenda laid out by Schmidt and Bannon.

2.2 Initial Work on Information Infrastructures

Some years ago, from the field of Participative Design, Henderson & Kyng (1991) put forward the idea of 'continuing design in use' to capture the (often unplanned) struggle to get workplace information technologies to work and be productive in a particular (organisational and technological) socio-technical setting. In particular they showed how complex organisational technologies often needed to be 'tailored' (i.e. that is taken apart, broken down, adapted and reconfigured). This suggested that technological development often carries on within the later stages of implementation and use – and Henderson & Kyng (1991) proposed the notion of 'continuing design in use' to capture this. The importance of this work – but not something particularly highlighted in CSCW - was that this was an attempt to suggest that design was beginning to be stretched out in both time and space.

Karasti et al. (2010, p. 407) take up this point to critique what they see as focus on 'short-term temporal aspects' in CSCW discussions of workplace technologies. This 'bias' (their word) is at the expense of a longer-term view which they see important when dealing with II type developments. They attempt to broaden Henderson & Kyng's original work through blurring the distinction not simply between design, implementation and use but also later stages like maintenance and redesign. Karasti et al. (2010) further supplement Henderson & Kyng's work through developing the term 'continuing design'. This is, in their words, a "development orientation where the relation between short-term and long-term—traditionally seen as a tension—is addressed and accounted for from the point of view of infrastructure time by incorporating it as a foundational design consideration" (2010, p. 407). This re-orientation is necessary because IIs work according to very different timescales than more traditional IT projects. The former endure over periods of multiple decades or what Karasti et al. (2010) call 'infrastructure time', whereas the latter work according to periods of 3 to 5 years or what they call 'project time'.

Their work raises the question of how CSCW type analysis might finds ways to focus on these multiple/longer temporal scales. This was also the focus of a recent special issue in the *Journal of the Association for Information Systems (JAIS)* where Edwards et al. (2007) similarly note how because IIs result from large-scale, protracted investments they tend to have very long timescales. They also point to how because IIs are typically erected on the foundations of earlier systems development and implementation work this means that infrastructures come into contact with other systems based around different purposes, standards or classification systems. Edwards et al (2007) thus suggest it may be more helpful to apply a metaphor of 'growing' rather than designing or building infrastructures. The term attempts to capture "the sense of an organic unfolding within an existing (and changing) environment" (2007, p. 369). This means that with infrastructures there is a "recurring issue of adjustment in which infrastructures adapt to, reshape, or even internalize elements of their environment in the process of growth and entrenchment" (2007, p. 369).

Edwards et al. (2007) also note how these are the 'points' at which most systems fail to become infrastructures:

> They cannot successfully link with other systems, adapt to a changed environment, or reshape or internalize elements of the environment in order to grow and consolidate.

> A principal reason most systems fail is that these critical moments are difficult to anticipate or plan for, and rarely lend themselves to deliberate design (2007, p. 369).

Edwards et al. (2007) have described how difficulties in aligning the entrenched differences between these local systems generate pressures of competition or accommodation between systems that may be resolved through the creation of ‘gateways’, which allow multiple divergent systems to interoperate. The tensions and discrepancies between these local systems may in due course generate pressures leading to periodic adjustments and redevelopments to accommodate changing internal and external circumstances (Ribes and Finholt 2009).

Infrastructure development and evolution thus involves simultaneous work on many fronts. For example, infrastructure design needs to serve as a bridge forwards towards future anticipated users/uses. At the same time, infrastructure implementation involves building workable bridges between necessarily generic features of the e-infrastructure and the particular locales of use. In this respect Ribes and Finholt (2009) note that those trying to initiate, promote and grow infrastructures need to integrate the ‘demands of the present’ with those imagined as important in ‘ the future’—which they describe, after Braudel (1949), as ‘The Long Now’ (longue durée). Their article points to the way attempts to grow infrastructures are often highly unpredictable and prone to failure. The sought-after future proof systems of today – which strives to cater for all purposes including those not yet envisaged – often end up becoming tomorrow’s legacy systems.

Ribes and Finholt (2009) paper also develop a much broader focus than typical of CSCW in that they see the work of growing IIs as altogether more heterogeneous:

> The problems participants articulate span much broader scales than technology development: they speak of encountering difficulties in the spheres of science policy, funding, organizing work and maintaining technical systems (ibid., p. 376).

To capture the range of activities that II participants might be engaged in they talk of ‘scales of infrastructure’. The three scales described in their paper include: enacting technology (‘creating bridges between, for example, experimental and production systems or design intents and user requirements’ (ibid., p. 378)); organising work (the organizational arrangements that make long term projects possible); and institutionalizing (linking projects to wider longer term goal beyond those of the project team).

A further JCSCW contribution explicitly employing an infrastructure perspective is Karasti et al (2006). They study data curation practices looking at a longitudinal e-Science data collection project. Key to their analysis is the role of standards for terminology (metadata) and the relationship with the different local ‘dialects’ used by the involved communities of scientists. They conclude (ibid., p. 352) by underscoring the importance of “developing an understanding of and attending to unavoidable tensions and conflicts whether in balancing multiple timeframes or local-global options" but refrain from spelling out strong theoretical, methodological or practical implications from their study.

In a series of studies within the healthcare sector published in JCSCW (Aanestad 2003; Winthereik and Vikkelsø 2005; Hanseth and Ljungberg 2001; Ellingsen and Monteiro 2003, 2006) various authors explicitly draw on an II perspective. In doing so they highlight how a comprehensive network of distributed practices and modules need to operate in tandem with the collaborative technology in question (Aanestad 2003). Winthereik and Vikkelsø analyse tensions arising in attempts to standardise communication between hospitals and general practitioners, underscoring their inherently differences in interests. They conclude, interestingly enough, not that standards are only an 'iron grid' imposed on situated practices but how their "...analysis also points to how it may be possible to further the integration of healthcare organisations through standardisation" (ibid., p. 61) before then going on to exemplify this claim.

All of this work calls into question in one way or another traditional privileging of design in much of the CSCW literature and its treatment of design as a discrete, prior episode in isolation from implementation. It also questions the focus on the immediate circumstances surrounding workplace information technologies (what we referred to above as its 'here and now' focus). Thus we argue for a revitalised agenda on CSCW and put forward our II perspective as a constructive response to Schmidt and Bannon's (1992) principal objection to broaden the empirical phenomena to make CSCW study about:

> systems that support cooperative work arrangements that are characterized by a large and maybe indeterminate number of participants, incommensurate conceptualizations, incompatible strategies, conflicting goals and motives, etc. (ibid. pp. 17-18).

With such a broadening of the empirical phenomenon, there is an accompanying need to develop theoretical perspectives which we argue is offered by II.

At a more schematic level we see IIs to be different from more conventional systems in that they are characterised by the following components. IIs are characterised by *openness* to number and types of users (no fixed notion of 'user'), *interconnections* of numerous modules/systems (i.e. heterogeneity of purposes, agendas, strategies), dynamically *evolving* portfolios of (an ecosystem of) systems and shaped by *installed base* of existing systems and practices (thus restricting the scope of design, as traditionally conceived). IIs are also typically stretched across space and time. That is, they are shaped and used at many different level and endure over long periods (decades rather than years).

Schmidt and Bannon (1992, p. 17, *emphasis added*) exemplified what an empirical broadening of CSCW could imply by identifying Computer Integrated Manufacturing (CIM).

Seemingly in the way they see it CIM had disappeared from the CSCW radar despite the fact that it adhered to many of the field's core ideas:

> The ambition of the efforts of the Computer Integrated Manufacturing (CIM) field is to link and fuse the diverse information processing activities of the various manufacturing functions such as design and process engineering, production planning and control, process planning and control, purchasing, sales, distribution, accounting, etc. into a unitary information system.... A CIM system embracing these information processing activities on a company-wide scale should be seen as a unified database system facilitating and supporting the horizontal and hierarchical, indirect and direct, distributed and collective cooperation of a heterogeneous ensemble of distributed decision makers throughout all functions of manufacturing. *CIM is thus faced with issues that are crucial to CSCW*.... However, despite the large amount of work on CIM, and its obvious pertinence to the CSCW field, this domain is almost totally absent in the work of the CSCW community. In our view, this is a loss to the field.

Since then CIM has since developed into an industry and become a central topic for scholarly study for allied fields like Information Systems Research – albeit under its current name, Enterprise Resource Planning (ERP) systems or simply Enterprise Systems (ES). Recalling Schmidt and Bannon's (1992) words we believe it is a loss to CSCW that workplace information technologies like these – integrated, interconnected, large-scale, or simply: an II – have not attracted CSCW attention. In the 20 year history of JCSCW, for instance, we are surprised to find that there are no ERP studies (based on a free-text search of online archives). The lack of ERP/ES studies in CSCW illustrate the more general and important problem of a relative neglect of an II agenda in CSCW.[1]

In the next section we present and discuss cases of collaborative work (interdependence of work) stemming from integrated, interconnected technologies exemplified but not restricted to ERP/ES.

3. Standardisation

An important expression of CSCW's localist sentiment is its privileging of concepts about how:

> ...technologies are 'imported' ('domesticated', 'appropriated' or 'worked-around') into user settings, while there is comparative lack of emphasis on the reverse process through which an artefact is 'exported' from the setting(s) (Pollock and Williams, 2007, p. 256)

1 The one study we did find about ERP outwith JCSCW but from a CSCW perspective exemplified similar aspects of the more general information systems literature in highlighting the gap between expectations and outcomes. Taylor and Virgili (2008, p. 68), for instance, write: "...it then became possible to conceptualise the gap between current modes of working, and those that SAP envisioned. As this process transpired, however, the complexity of the SAP technology was also beginning to reveal itself. How to reconcile accepted practice and new system now became less a simple matter of identifying discrepancies and correcting them than it did of finding a way to deal with the intractable realities of practice either by modifying the technology, or abandoning the practice—or both. This was not exactly the way the development process had been envisioned. It was more complex—considerably more".

A localist focus fails to tap into broad organisational changes, tensions and trends towards internal harmonisation ('best practices') of work practices alongside the progressive outsourcing of functions together with (quasi-)market arrangements, made possible through elaborate inter-organisation networks (Pollock & Williams 2009). This is important because the boundary of an organisation, the distinction between intra- and inter-organisational collaboration, is increasingly blurred. Addressing these organisational trends is a tall order, arguably one too comprehensive for a CSCW agenda. Aspects of the trends, however, are crucial to include. We believe the central theme of *how* technology mediates 'harmonisation' (or standardisation) of work practices is one that does/or should belong to CSCW. The practical relevance of addressing standardised work practices comes from empirical examples (including ES /ERP, packaged technologies, inter/ intra-organisational networks) where collaboration imply significant forms and levels of standardisation (Pollock & Williams 2009).

Conceptually, CSCW has routinely documented how collaborative technology produces different outcomes for every implementation, also for the same technology. This leaves unaccounted for the empirically observable (degrees of) similarities in work practices. As Leonardi and Barley (2008, p. 161) note, the malleability of the use of collaborative technology is by now well-rehearsed and

> more can be gained by asking why different [contexts] experience similar outcomes of the same technology.

With an II perspective collaborative technologies serving multiple, similar use communities will necessarily rely on forms of standardisation (standardisation is the only way these similarities in demand can be met). The question within II, then, becomes an empirical one of how standardisation plays out. In other words: *what* exactly is standardised (and what is not); *when* in the biography of the technology does standardisation happen; and for *whom* does standardisation apply? We illustrate these questions with examples from our own work.

3.1 Reflexive standardisation[2]

The MEDAKIS Electronic Patient Record (EPR) project started in 1996. It was a collaborative effort between the five regional (largest and most advanced) hospitals in Norway and the IT vendor Siemens. The aim was to improve the quality of patient care by replacing the exiting fragmented and often un-available paper based patient record by an electronic one which would make any information instantly available to anybody, anywhere and anytime. The anticipated EPR system had a number of ambitions aims: it should include all clinical patient information, covering the needs of all users; it should be built as one single

[2] This case is more extensively described and analysed in Hanseth et al. (2006).

integrated system; it should enable better collaboration and coordination of patient treatment and care through electronic information sharing and exchange; and the aim, importantly, in the contexts of the arguments developed in this paper, was also that the system should be a standard EPR solution for all Norwegian hospitals. The deadline set for the delivery of the final system was the end of 1999. The project started with the best intentions of involving users, acknowledging current work practices, and favouring a bottom-up development strategy. Alas, the outcome turned out to be very different.

Shortly after it began, project members became aware that within Siemens EPR projects were also underway in Sweden, UK, Germany, and India. Moreover, they realized that the Norwegian project was not at the top of Siemens' priorities since Norway represented the smallest market. This meant there was a high risk of overrun as Siemens prioritised more profitable markets. As a consequence, the project members decided to make moves towards 'internationalizing' the project, first to a Scandinavian level and later to a European one. However this decision weakened the consortium's position with respect to Siemens, since now the requirements from all projects from across countries would need to be merged and a new architecture designed (called IntEPR).

In 1999 Siemens acquired a large US software development company. As a consequence, Siemens' medical division's headquarters was moved from Europe to the US, and the project's scope became global (this meant the IntEPR architecture was dropped in favour of a new system called GlobEPR). And as the number of involved users grew, large-scale participatory development became unmanageable. After a few years, only a small number of user-representatives from each hospital continued to actively participate in the development. Moreover, the need to continuously find common agreements between the hospitals turned the intended bottom-up approach into a top-down one.

Also the efforts aimed at solving the fragmentation problem with a complete and smoothly integrated EPR system turned out to be more challenging than foreseen. Paradoxically, the volume of paper records increased and the patient record became even more fragmented – for various reasons: First, new laws on medical documentation required detailed records from professional groups not previously obliged to maintain a record, such as nurses, physiotherapists and social workers. Second, for both practical and legal reasons the hospital had to keep updated versions of the complete record. And as long as lots of information only existed on paper, the complete record had to be paper based. Thus, each time a clinical note was written in the EPR, a paper copy was also printed and added to the paper record. Printout efficiency was not a design principle for the current EPR, causing non-adjustable print layouts that could result in two printed pages for one electronic page form. Third, multiple printouts of preliminary documents (e.g. lab test results) were often stored in addition to final versions.

The result was that the volume of paper documents increased. This growth created a crisis at the paper record archive department. The hospital had moved into new facilities designed with a reduced space for the archive as it was supposed to handle electronic records only. In 2003 the archive was full and more than 300 shelf meters of records were lying on the floors. This situation also affected the time needed to find records, and often requests failed to be satisfied.

When the implementation of a system called DocuLive started, five local systems containing clinical patient information existed. The plan was to replace these with DocuLive so as to have the EPR as one single integrated information system. In spite of this, the number of local systems was growing at an accelerating speed, based on well justified needs of the different medical specialties and departments. For example, the in-vitro fertilization clinic needed a system that allowed them to consider a couple as a unit, as well as allow tracking of information from both semen and egg quality tests through all procedures involved, up to the birth of the child. The intensive care unit acquired a system that allowed them to harvest digital data from a vast array of medical equipment and thus eliminate the specialized paper forms previously used to document events and actions. Moreover, new digital instruments in use in many different departments include software components with medical record functionality. The number of such specialized systems had grown from 5 in 1996 to 135 in 2003.

The original plan said that the final system should be delivered in 1999. Four years later, towards the end of 2003, the version of DocuLive in use included information types covering between 30% and 40% of a patient record. This meant that the paper record was still very important, but unfortunately more fragmented and in-accessible than ever. The increased fragmentation was partly due to the large volume of paper caused by DocuLive printouts, but also the high number of specialized systems containing clinical patient information. And by 2003, another EPR system, called DIPS, emerged as a far more successful one. This development of this system also started around 1996. It started as a very small local initiative at a small hospital in northern Norway. The first version of the system was perceived as very useful by its first small group of users. This attracted more users and the system started growing both in terms of users and functionality. By 2003 it was clear that this one was becoming the Norwegian standard solution.

How can this sad story be explained? This was firstly to do with the complexities involved and secondly how these complexities were managed. The primary complexity involved is that of the work practices related to patient treatment and care. By trying to make one integrated system that should cover the needs of all hospitals in Norway, one brings together the total complexity of these practices. The hospitals realized that dealing with this was demanding.

Accordingly, they concluded that they had to involve a supplier that was strong both in terms of ICT competence and economy. So Siemens was chosen. But then the complexity of Siemens was merged with that of the hospitals. The medical division within Siemens is large, with a traditional base within medical imaging technologies. The imaging instruments have become digital and supplementary software systems have been built. As the EPR development activities were increasing within Siemens, it became more and more important to align and integrate the EPR strategy and product(s) with other Siemens products and strategies.

Within this world, Norway becomes marginal, as the appetite for larger markets escalates in a self-feeding process. A side-effect of the expansion of ambitions and scope was increased complexity: the larger the market Siemens was aiming at, the more diverse the user requirements, and accordingly, the more complex the system had to be in order to satisfy them. This implied that the development costs were growing, which again implied that a larger market was required to make the whole project profitable.

The growing complexity also slowed down the progress of the project and made it harder to satisfy user requirements. This contributed to the explosion of the volume of the paper records, the users' demand for alternative solutions and accordingly the growing number of specialized systems, and finally, that DIPS became the standard solution in Norway.

At Rikshospitalet, where we carried out our study, they decided to change their strategy and approach complexity in quite different way in 2004. They realized that the idea of one complete EPR system had failed. Instead they decided to 'loosely couple' the various systems containing clinical patient information underneath a 'clinical portal' giving each user group access to the relevant information in a coherent way. This strategy turned out to be successful.

3.2 Generification

We return to and expand on this theme of design for a 'market' rather than a specific user in this next example of ERP design. As already mentioned we find it interesting that not only have few CSCW studies of Enterprise Resource Planning systems been conducted but also how there is also little apparent interest in how large scale packaged systems more generally are used to support the needs of so many kinds of user organisations (but see Martin et al. 2006). The extension of packaged ERP systems across organisations, sectors and countries is all the more intriguing when one considers that some CSCW proponents insist that information systems must be built around the unique exigencies of particular organisations (Hartswood et al. 2002). In our research we were able to document and explore how, in their design and development decisions, suppliers of standard ERP packages were able to build viable ‘bridges’ to diverse organisational users through various kinds of generification work (Pollock et al. 2007).

3.2.1 Generifying the Needs of Different Users in the Design of an ERP Module

‘Generification’ involves a complex set of interactions and alignment efforts between the developer and its wider user community. Our studies over more than a decade revealed a number of linked strategies deployed by ERP suppliers to manage this process including segmenting their market, enrolling selected user organisations as development sites and as members of ‘user groups’, and subsequently by sorting, aligning and prioritising user requirements. For example, when a major ERP supplier moved into the Higher Education sector, we saw how it enlisted a number of ‘pilot sites’ from around the world to help it identify homologies of practice that would be implemented in its new potentially global student management module. The supplier invited these pilot sites to regular week long requirements gathering sessions at its European headquarters. There they would sit together in one large room and articulate in detail their requirements for the new system. This was often a laborious and frustrating process where the sites would highlight their differences between each other. In the excerpt that follows a supplier employee is discussing the storing of student transcripts and whether universities need to store details on both passed and failed courses:

> ERP Supplier: Does everyone want the ability to store two records?
>
> America South Uni: We would maintain only one record…
>
> ERP Supplier: Is there a need to go back into history? If transcript received and courses are missing, do you need to store this?
>
> America North Uni:…no record is needed.
>
> America South Uni: We need both to update current record and then keep a history of that…
>
> Belgium Uni: In our case, things are completely different!

Later, through what we describe as ‘process alignment work’ and ‘smoothing strategies’, we saw how the pilot sites were encouraged and incentivised to shift from highlighting their differences between each other to actively searching for similarities. This was not so much a search for identical ways of doing things but an attempt to establish limited spreads of practice that could be handled in similar ways by their necessarily generic software package. For instance, one supplier employee asks participants to describe their rules for progressing students from one year to another and to explain how a student’s grades contribute to his/her overall programme of study. A complicated conversation develops, with various people interjecting. The supplier struggles to bring the discussion back on topic by attempting to summarise and ‘name’ the particular process being described:

> ERP Supplier: We've got one aspect now. Just want to get some common things. How [do] we name the baby? Let's go to the grading issue. Want to specify if module will contribute to programme of study in any way as a credit or grade. Is there any rule how it contributes? Is it linked to students? What is it linked to that it gives credit?
>
> Swiss Uni: Could be a rule or a decision given by someone?
>
> South African Uni: The student can still do the exam and be graded, but it might be true that the grade or credit did or did not influence the student's progression…
>
> Canadian Uni: We wouldn't use these rules: we take all courses into progression. We have rules based on courses students take.
>
> ERP Supplier: It is the same at [America North Uni]. It is the US model. It is the difference between the European and the US model.

When faced with diverging requirements, the establishment of generic features seems impossible. However, the analyst does not admit defeat but accepts the next best thing to a single generic process: 'two' generic templates (the US and European model of doing things). In other words, the supplier was able to establish equivalences between disparate organisations around a manageable level of diversity which their package would cater for in its generic functionality.

3.2.2 Not all Requests for Generification are Answered

This is not to suggest, however, that every request was included in the module. Certain requirements were in contrast rejected as 'university specific'. A university from Belgium, for instance, reports in a series of emails to the other pilots how:

> We have the feeling that it's becoming a strategy to try to label issues as 'university specific until proven differently'. Should it not be the other way around? Should [the supplier] not search for generic concepts behind the specific situations at the different pilot universities? (email from Belgium University to pilots)

These were design choices that reflected the operation of a complex 'political economy' as the supplier established boundaries around the market for its product. In practice this meant that product enhancement proposals were assessed not only against the needs of the other pilots but also the standing of that particular customer, its representativeness and importance to the supplier. Importance in this respect was related to whether the market the user organisation inhabited was large or growing and/or seen as strategic for future development. There was very much a 'hierarchy of users' with at one end of the spectrum those who could command the attention of the vendor and exert influence over product development strategies whilst at the other end, for instance, were the 'transactional users'. These were the organisations which the supplier treated on a more strictly commodified basis—offering to install additional functionality only if they paid for it. Our study revealed the array of techniques that suppliers had developed to manage this process—to align and organise its relationship with their user markets and achieve effective closure around product features.

Clearly the strategies described above by vendors are far more sophisticated than the dismissive portrayals of suppliers neglecting specific user requirements that we tend to read about. Nor do we think the strategies adopted by this supplier to be unique. Johannessen and Ellingsen (2009), for instance, noted the different challenges in the supply of health information systems that were designed initially for one setting but then transferred to other contexts and subsequently to a larger market. The generification strategies adopted by the supplier in their study bear striking resemblances to the generification strategies articulated over time by ERP suppliers:

> Often vendors want to reuse much of their software code in order to optimize payback and to manage different implementations at different sites in a relatively similar way. It is therefore imperative for vendors to carefully balance the boundary between the particular and the general functionality while at the same time trying to expand…the general part of it. A basic strategy is to try to align the user communities in order to obtain common requirements… (ibid. pp. 627-8).

3.3 Standardised Nursing Reports/Codes

Turning now to a different kind of example, Ellingsen et al. (2007) report on the standardisation of one central aspect of nurses' work – that of 'reporting'. Reporting is essential to nurses' work (e.g. during hand-over: the reports are crucial in achieving a continuity-of-care across time and space during a patient trajectory). Traditionally, nurses' documentation has been informal (free-text, in part oral). The increased formalisation of nurses' documentation is, on the one hand, part of nurses' on-going efforts to 'professionalise' nursing (i.e. adopting physicians' practices) and, on the other hand, an effort to promote quality and efficiency of care.

Ellingsen et al. (ibid.) describe how a nursing reporting module embedding the American Nursing Association's standards for diagnoses and interventions (so-called NANDA and NIC, respectively) was embedded into a Norwegian vendor's system implemented in a hospital in Northern Norway. Beyond numerous instances of 'working around' the imposed standards, a theme well-rehearsed in the CSCW literature, Ellingsen et al. (ibid.) more importantly also demonstrate how the users *modify* the standards to make them work. In other words, redundancy was (re)introduced to make the standardised reporting more robust. Certain instances of redundancy of information fill productive and practical roles in on-going work. Although certain information was already contained in the plans, the daily report might repeate the content of the plan:

> Sometimes things are registered twice, that is, what is in the report you may also find in the nursing plan. This has to do with experience. . . I know that the report is read aloud at the change of shift meeting while the nursing plan is not.

In response to an inability to decide uniquely how to classify interventions, a common strategy is to duplicate the information by entering it in both possible places, but slightly rephrased to 'cover up' the duplication.

Moreover, the system may induce surprising consequences, as the fitting of the system to some users' situation simultaneously makes it unfitting for others. The standardisation of nursing plans unintentionally subverted the possibilities for interdisciplinary cooperation, that is, benefits for nurses simultaneously produced disadvantages for the psychologists and physicians. The ward relied on interdisciplinary work between the nurses on one hand and the physicians and psychologists on the other. The previous, free-text narrative contained in the old reports had been the glue in this collaboration:

> Several of the nurses sum up in their own words after we have had a treatment meeting [for a patient]...they write good and extensive notes, especially when something extraordinary has happened...Therefore, when I write my own report I often refer to the report written by the nurse (psychologist)

This illustates the important phenomenon, regularly left out in localist accounts, where interactions with the technology at one site produce 'ripple effects' that influence interactions elsewhere/for others.

4. Heterogeneity

A central source of materially mediated 'interdependence of work' is those stemming from the interconnectivity of multiple in part overlapping collections or portfolios of modules/systems. Again we quote from Schmidt and Bannon (1992, pp. 17-18) who pointed out the relevance for CSCW of 'packaged' information systems:

> [w]e certainly want CSCW to address the aspects of computer support for cooperative work wherever they occur. In this sense, established research and development fields such as, for example, Computer Integrated Manufacturing (CIM), Office Information Systems (OIS), Computer-Aided Design (CAD), and Computer-Aided Software Engineering (CASE) are all legitimate and indeed necessary fields for CSCW as domains of inquiry... [O]therwise *CSCW will tend to ignore or even dismiss the major challenges posed by the design of systems that support cooperative work arrangements that are characterized by a large and maybe indeterminate number of participants, incommensurate conceptualizations, incompatible strategies, conflicting goals and motives, etc*.

Another way of thinking about this is through the notion of 'complexity' (Hanseth and Ciborra 2007). CSCW has grappled extensively with complexities of micro-practices (for instance the subtle interleaving of oral, ostensive and written cues in control room settings for collaboration [Heath and Luff 1992]). But what have received less attention are the more 'macro' level forms of complexities in collaboration. This includes how external aspects in the (business) environment influence how collaboration is to be exercised, or how collaborative technologies introduced as part of one project interconnect or interfere in nanticipated ways with technology and routines introduced in quite different projects. We exemplify these aspects through drawing on our research.

4.1 The Hydro Bridge Infrastructure[3]

The Hydro Bridge project was an attempt to define the standard for desktop applications within a large corporation. Norsk Hydro was established in 1905 and fertilizer was the only business area until the 1950s, when it expanded into light metals and later oil and gas. Around 2000 about 35,000 were employed around the world. In 1992 poor integration and communication across divisions and between the divisions and the corporate headquarter was widely acknowledged as a major obstacle for smooth operation of the company. Developing a corporate standard for desktop applications was seen as the solution.

This looked like a plain and easy task – a simple choice between Microsoft and Lotus products. The Bridge project decided, mainly due to costs, to go for the Lotus SmartSuite set of applications. Having decided on the content of the standard, there were still more issues to take care of. Among these was the scope of the standard. Who should use it and in which functions or use areas? Initially, those advocating the Bridge standard meant that there should be no other systems used by anybody inside Hydro for functions which Lotus SmartSuite products covered. However, to obtain required acceptance for the decision, the Bridge project group had to be open to using Microsoft products in some areas. These included areas where large software applications were developed in Excel for applications for the interpretation of data from lab equipment and for currency transformations in some budgeting support systems. Word was also accepted as the preferred word processor in several joint projects with other oil companies where the others required Word (or other Microsoft products) to be used as a shared platform.

4.1.1 Product Development: Opening Pandora's Box.

The step following the formal approval of the standard was its implementation into a 'product'. As the standard specified only a set of commercial products to be used, this might seem unnecessary. That was far from being the case. Products such as those involved here may be installed and configured in many different ways. To obtain the benefits in terms of less cost installation, maintenance and support of these products, they had to be installed coherently on all computers. Such a coherent installation is also crucial for establishing a transparent infrastructure where information may smoothly be exchanged between all users. To reach these objectives, a considerable development task had to be carried out. The task included primarily bundling work in forms of developing scripts installing the applications in

[3] This case is more extensively reported and analyzed in Hanseth and Braa (2001).

the same way 'automatically'. Developing these scripts turned out to be a challenge with lots of unforeseen problems popping up.

To work as a shared II, this infrastructure itself required an extensive underlying and supporting infrastructure. Throughout the implementation phase, this included several underlying and highly heterogeneous or un-standardized layers which the project team then tried to include into the Bridge standard (operating system, PC specifications, networking operating systems, Local Area Networks, etc.). For each of them, defining a strict standard was impossible. The project had to allow for different varieties for each 'layer' and adapt the rest of the standard to this. In parallel with the implementation of the Bridge infrastructure, communication generally became more important. This implied that the global IP based network being built, Hydro InterLAN, also was included into Bridge.

4.1.2 Diffusion, Adoption and Use: Meeting the Local

The common view is that a standard is just one thing equal for all. That is not how Bridge appeared as the adoption process unfolded. It was seen very differently by the different units due to differences concerning existing computing environment, available resources in terms of money and competence, cultures concerning management styles as well as use of technology, felt need for improved infrastructure, etc. The adoption speed and style also depended on the distance from the main office of Hydro Data. For those already using Lotus products, adopting Bridge meant doing almost nothing. Others had to change considerably. Bridge soon came to encompass several different systems. This implies that some implemented the whole package, others just a few components. In the latter group you would find smaller offices in Africa, for instance, typically having just a few stand-alone PCs.

Differences in strategies among the different units have implied that the Bridge is not implemented as one coherent universal package, but rather as many different ones which need to be integrated and linked together to make the overall infrastructure work. This became an increasingly more salient and challenging issue as new versions were specified and adopted by some units while other want to stick to the version they were using for as long as possible.

4.1.3 Applications Integration: Including the Environment

The users of Bridge application also use a series of other, 'external' applications. Some 'external' applications share data with Bridge applications or are used together with Bridge applications in an integrated way. For these reasons, many users wanted their applications to be integrated into the Bridge standard. Some were tightly integrated with the original Bridge applications and included into the standard. Typical examples included various Internet applications such as a web browser. Some applications were integrated with Bridge applications through mechanisms for exchanging data. Yet other applications emerged as tightly coupled to Bridge in completely different ways. An important example here was the SAP implementation in the European Fertilizer Division. The basic Bridge infrastructure (PC's, network, OS, etc.) was also the infrastructure on top of which SAP was running. This SAP implementation was a huge one, so the IT manager in charge concluded that Hydro itself did not have the resources and competence to take responsibility for the required data processing and operations services. So they decided to outsource these functions to a major global company offering such services.

The SAP transaction processing would run on computers physically located at a large processing centre in UK. When the decision about outsourcing SAP processing was taken, IT management thought it would be an advantage if the same service provider also delivered the required network services connecting the client software on local PC's to the servers. So they decided to outsource that as well. Moreover, they also believed it would be beneficial to have just one provider responsible for the whole chain from the servers running the SAP databases through the network to the hardware equipment and software applications used locally. Accordingly, a contract was signed covering three areas. At this time Bridge had been extended to include Hydro's global network. This contract meant than that the design and operation of the Bridge network was handed over to the service provider, as was the responsibility for installa-tion and support of all elements of Bridge locally (PC's operating system, desktop applications, the Notes infrastructure and applications, Internet software and access, etc.).

The outsourcing was a mixed blessing. The network and processing services were fine, but site management (i.e. local support) was highly problematic. The major problems seem to be related to the fact that the actual global service provider has organized its business in independent national subsidiaries, and are not able to carry out the required coordination across national borders. In addition, some problems are related to the fact that the site management contract specifies that users should call the help desk in UK when they need support. The threshold for doing this is quite high for large user groups not speaking English, although the help desk should have people speaking all major European languages. When getting in contact with the help desk, problem solving is experienced to be much more difficult than when getting assistance from local support personnel. In this way SAP has made the support of Bridge far more complex than desired.

4.2 Subsurface Ecology

Contrary to much of the focus in CSCW, collaboration is quite often not 'supported' by a singular system but emerges from the 'juggling' of multiple ones. That is, collaboration is patched together by criss-crossing across collections of systems. Hepsø et al. (2009) provide an illustration where they study the subsurface community of an internationally oriented oil and gas company. The subsurface community consists of different disciplines including geologists, geophysicists, reservoir engineers, production engineers, well engineers and process engineers. In their daily work, they rely on about 20 highly specialised (‘niche’) systems for collecting, analysing and presenting information that feed on-going discussions and collective decision making.

To encourage more collaboration across disciplines and assets (i.e. geographical sites) within the subsurface community, three major infrastructures for collaboration have been introduced of the last 15 years. First, relying on shared network disks organised to mirror geographically dispersed assets, then a strategic initiative to migrate to Lotus Notes before the on-going migration to MS Sharepoint.

Following the company’s listing on the New York Stock Exchange, there has also been renewed and vigorous attention placed on systematic documentation. In response to the major financial crises (notably Enron), new legislation both in the US and in Europe has emerged to increase the traceability and accountability of business transactions and critical decision processes. In the US the Sarbanes-Oxley (SOX) Act of 2002 has driven the need for effective internal control systems built on heightened requirements for documentation of key organizational decision points (cf. paragraph 404 of SOX). In the company, this implied increased pressure for the subsurface community - the principal source of value generation in an oil and gas company - to make business relevant decision making more transparent and auditable.

Despite intentions of migration (i.e. gradual *substitution* of the new for the old infrastructure), what has taken place in recent years is a historical stratification resulting from the *superimposing* of the new on top of the old. For members of the subsurface community this entails that locating information relies on a combination of ‘indices’ and heuristics to navigate. As noted by an experienced production engineer, this is not a straightforward task for rookies:

> If you didn’t follow the well from its inception, there is no way you can know where to find the information or what kind of information that is available. Thus, it is also impossible to just use the search engine

As expressed by a production engineer:

> The G-drive is a good alternative. You can always expect it to exist. But, again, the problem is that we have a complex tree-structure [of folders] and you need to have been working here for some years in order to find something.

As stated by an experienced production engineer responsible for a number of sub-sea wells, the problem is “that you don’t get all the data needed in one single system”. For example, when conducting ‘well testing’, the production engineers in one asset use a front end to the logging system in order to survey the wells’ temperatures, pressures and rates. If a test is successful, information about a certain well is transferred to the production systems. However, this information is neither sufficient nor specific enough to calculate production rates. To compensate, engineers will typically select a data-set representing a certain period of time (for example a month), and then import this into a spreadsheet using a pre-programmed macro function. However, since each subsea installation consists of a template with four to six wells, and rates need to be estimated for each well, this is done more or less ‘by hand’ in the spreadsheet. As one production engineer reports, “We have to manually assign production to the different wells.”

The production trajectories of oil and gas wells are maintained and *constructed* historically across technological platforms and disciplinary as well as geographically boundaries.

5. Discussion: ‘Informing’ design, revisited

CSCW has spent considerable energy with discussions about how to ‘inform’ design from micro-oriented, typically ethnographically inspired work place studies (Hughes et al., 1992; Plowman et al., 1995; Voss et al. 2009; Karasti 2001; Randell and Shapiro 1992). The rich empirical picture of workplace activities that can be achieved by ethnographic research is envisaged as helping overcome the difficulties encountered with traditional methods of ‘requirements capture’ that only engage with the formal descriptions of how work tasks are supposed to be undertaken. By drawing attention to the range of informal procedures through which work goals are carried out, including dealing with frequent ‘abnormal instances’, such studies were seen as providing the information required for designing tools and systems that could better support the ways in which work activities are actually performed (Plowman et al. 1995; Luff et al. 2000). However this goal has proved somewhat elusive for a number of reasons (Ackerman 2000; Schmidt 2000; Stewart and Williams 2005). In particular, those involved in design stressed the difficulties of packaging sociological understandings into a form that could inform workplace analysis and design (Dourish 2001; Fitzpatrick 2003). The social scientists involved conversely raised two sets of questions. The first revolved around what kind of empirical investigation was needed to acquire an adequate understanding of work settings. The developers’ need for timely information about potential users and uses, and the prohibitively high costs of protracted labour intensive ethnographic research, prompted suggestions for the adoption of ‘quick and dirty’ ethnographies, which could yield information better targeted to designers’ needs and in more manageable volumes (Hughes et al. 1994; Anderson 2000; Martin and Sommerville 2006).

As Karasti (2001, p. 235) points out, “[m]any studies have described ethnographers as mediators between the work place and systems development”. In a critical response to such a role for ethnography, Dourish (2006, p. 543) complains that this would unduly reduce work place studies and ethnography to a mere “toolbox of methods for extracting data from settings,” so “aligned with the requirements-gathering phase of a traditional development model”. Dourish (ibid.) goes on to suggest an almost ritual adherence in research papers with an ending section entitled ‘Informing design’.

Despite differences in position within this debate, there is a shared - and from an II perspective, highly problematic - assumption that ‘design’ is a relatively local activity (i.e. confined in time and space). This is exactly the opposite of what an II perspective would provide. Rather – and as was shown with the examples above -infrastructure design is an activity distributed in both time and space and involves a large number of actors of various kinds. Infrastructures are not designed from scratch – they are normally designed just by modifying and extending what exits. So the infrastructure as it is – the installed base - has a strong influence of what it may be in the future. Accordingly, we have called infrastructure design ‘installed base cultivation’ (Hanseth et al. 1996; Hanseth and Lyytinen 2010). We will here briefly present some specific ideas about infrastructure design.

5.1 Design as Generification

In setting out the Biography of Artefacts (BoA) framework, closely tied to an II perspective, Williams and Pollock (in press) highlight how current conceptions of the development and evolution of ERP systems have a number of limitations in respect of space (actors and arenas), time and the broader institutional context.

The design, development and evolution of a large ERP package do not occur in one *space* only (such as the vendor organisation). Other sites (arenas) and actors that normally receive CSCW’s attention are highlighted. The *actors* involved in shaping and developing a package are not only those found within the vendor organisation (rather enterprise solutions are surrounded by a large number of external experts and intermediaries). For instance, Pollock & Williams (2009) examined the user-group meetings of a number of package software vendors which allowed us access to the different character of linkages between technology supplier and user in relation to the different phases and locales in the biography of particular artifacts. When a vendor solution is seen to lack functionality, for instance, it is now not uncommon for the user group itself to seek a solution. Sometimes this is through lobbying the vendor directly or increasingly it can decide to develop its own software. Mozaffar (2011) recounts an example in her on-going study of a large UK user group where a major deficiency of the system became apparent (for an essential task called ‘encumbrance accounting’). The user group’s response was to develop the software themselves and pass this to other member organisations within the community and, importantly, back to the vendor where it is now included as a standard feature in their generic package that is sold onto others.

Similarly, Pollock & Williams (2009) have shown also how visions of emerging technologies help mobilize the material and intellectual resources needed for innovation. To give one important example, it was the industry analyst Gartner that initially coined the terminology of the technological field that became known as ‘enterprise resource planning’ back in the 1990s. Not only did Gartner coin the term but it went on, through its various assessments, to set out what functionality should be contained within ERP systems. Its sector reviews moreover consolidate the existence of a domain of technological activity (in this sense of constituting a technology like SAP’s R/3 as an instance of ERP), charting the overall development of particular technologies and their future development trajectory. The importance of this in relation to technology design is that vendors will often adjust their technologies and product road maps in line with the development trajectories set out by these experts.

A longitudinal (‘biography’) perspective on the time dimension of collaborative technology is scant. This is required as technological developments are not confined to one period of *time* (such as the initial development phase). For instance, scholars have called attention to how user organisations played a significant role in the development and evolution of new industrial IT applications. When generic systems are implemented they inevitably had to be adapted and tailored to fit the technical and operational circumstances of the adopting organisation. The recent history of information systems has shown that the process of ‘adaptation’ and ‘domestication’ that occurred as users attempted to make these generic system useful for their organisation often threw up useful innovations that were then fed back into future technology supply (Williams et al. 2005). Industrial automation artifacts were thus seen to evolve through successive cycles of technical development and industrial implementation and use – what Fleck *et al.* (1990) called a ‘spiral of innovation’ – as the generic package was developed and applied in ever more settings.

Finally, that studies are often impervious to the ways in which packaged solutions and their subsequent evolution are shaped by developments within the *wider terrain*. What Pollock & Williams (2009) argue, in contrast, is that design—and the coupling between artifact design and its implementation and use—is worked out through a range of different networks and intermediaries linking suppliers and users. This is the argument the character of packaged solutions is being shaped at a number of levels ranging from local contestation around features of artifact design or organizational implementation to the broad macro-level that they characterize as the technological field. It is also being worked out over multiple settings of organizational implementation (implementation cycles) and, in aggregated form, over multiple product cycles.

5.2 Enabling Infrastructure Growth: Bootstrapping and Generativity

Infrastructures are complex, so managing their evolution is largely about managing network externalities (or network effects) and path dependency (on network externalities and path dependence, see for instance Shapiro and Varian (1999)).

Network effects emerge because an infrastructure is a shared resource used by a larger community of users. So the use value of an infrastructure depends on the numbers of users using it. Accordingly, the value of and infrastructure (like email) is high for an individual when a high number of users is using it already, but zero (or close to) for initial users. This means that most users will adopt an infrastructure because other users will have adopted it first. This creates a chicken and egg problem, or a kind of deadlock, not addressed by traditional design approaches: Designing new infrastructures, then, requires that we break this deadlock. One way to do so is to design the first version of the new service so that it delivers value to the very first users beyond the benefits they will get when more users are using it. As the numbers of users grow, further users will adopt the infrastructure because of the value generated by the numbers of users already on-board. In general terms, an infrastructure will grow more and more in an automatic way, because of network effects, the larger it is. But the critical challenge, then, is to bring the network into existence and to make it grow (i.e. *bootstrapping* the network) (Hanseth and Aanestad 2002, Hanseth and Lyytinen 2010). Successful bootstrapping of a new infrastructure also requires that it is as cheap and simple to adopt as possible for the first users. That can normally best be achieved by using existing infrastructures (i.e. the installed base) as much as possible.

When an infrastructure (or network) starts to grow, another challenge emerges: Because of its complexity it becomes harder and harder to change, and because of network effects/externalities it becomes less and less attractive to start using an alternative one. To help overcome this *lock-in* problem, it is important to keep the infrastructure as simple and flexible as possible at the same time and *gateways* may be important tools to enable a smooth transition from one infrastructure to a new improved one (Hanseth et al 1996; Hanseth 2001).

Another strategy for stimulating continuous growth and improvement of an infrastructure is to make it as *generative* as possible (Zittrain 2006). This formulation should be seen as an attempt to generalise from the insights about why the design of the Internet has been such a success.

Generativity is “the essential quality animating the trajectory of information technology innovation” (Zittrain 2006, 1980). It “denotes a technology’s *overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences*” (ibid.). Zittrain argues that the grid of computers connected by the Internet has developed in such a way that it is consummately generative. More specifically, the Internet has proved to be a generative infrastructure by the continuous and rapid development of new innovations extending its overall functionality and range of services provided. The generative capacity of the Internet is attached, by Zittrain and others, to the combination of its end-to-end architecture and the programmability of its terminal nodes (i.e. the computers linked to the network). End-to-end architecture means that the network’s functionality is located in the networks ends. This is the opposite to traditional telecommunication where the functionality has been located in the network at the same time as the terminal nodes (i.e. the telephones) could not be modified or programmed after their production (i.e. they were just appliances). This means that anybody having a computer connected to the Internet may develop and provide new services while in the case of telecommunication only network owners could do the same.

Zittrain defines generativity in a more detailed manner as a function of a technology’s capacity for leverage across a range of tasks, adaptability to a range of different tasks, ease of mastery, and accessibility. *Leverage* describes the extent to which these objects enable valuable accomplishments that otherwise would be either impossible or not worth the effort to achieve. *Adaptability* refers to the breath of a technology’s use without change and the readiness with which it might be modified to broaden its range of uses. A technology’s *ease of mastery* reflects how easy it is for broad audiences to adopt and adapt it: how much skill is necessary to make use of its leverage for tasks they care about, regardless of whether the technology was designed with those tasks in mind. *Accessibility* – the more readily people can come to use and control a technology, along with what information might be required to master it, the more accessible the technology is.

This perspective involves a radical respecification of what is entailed by design. Supplier offerings are ‘unfinished’ in relation to final user requirements and uses (which are evolving in response to the availability of new technical capabilities and affordances), and must be completed by various intermediaries (e.g. system implementers) as well as through the creative engagement of final users (users organisations, work groups and individuals) in domesticating it to their purposes (Williams et al. 2005). A wide range of actors are contributing to this design process, as well as systems engineers, through processes of artful ‘configuration’ – selection from a range of already developed elements and option to meet particular local contingencies and purposes (Stewart and Williams 2005).

6. Conclusion

In writing this paper we are not on a crusade against either ethnographic or work place studies - *far from it*. Rather we are pushing for the broadening of the CSCW agenda and the development of new analytical frameworks to adequately capture the new empirical/technological developments we see around us. We thus call for greater attention to be given to issues of methodology and analytical framework so that we might escape what Kallinikos (2004) has dubbed the 'here and now' problem of practice-oriented studies. Moreover, it seems that the CSCW community has not responded adequately to the challenge embedded in Schmidt and Bannon's (1992) paper some 20 years ago. We do not offer a thorough/robust explanation of why this is the case – that is beyond the scope of this paper – other than to note that the CSCW field has acquired some of the qualities of 'normal science' (or, in the vocabulary of II, it has become a knowledge infrastructure with a considerable installed base)? The CSCW-in-use community has developed entrenched practices, methods and perspectives which are routinely reproduced institutionally through its dominant outlets. These run the risk of generating reduced forms of analysis.

We argue therefore for a gentle weaning of CSCW-in-use from its initial and founding preoccupations (the rather restricted, confined and specialised forms of cooperative witnessed over two last decades) towards a second wave of analyses that reflect the more open-ended agenda initially set out by Schmidt and Bannon (1992) but also now being reflected in the studies that are beginning to appear in JCSCW and other socially oriented computing outlets). If as Schmidt and Bannon's (1992) review suggest that *espoused-CSCW* was constituted around a particular 'problem situation', today, we would argue, because of important empirical developments, this problem situation has shifted somewhat.

Early CSCW scholars usefully drew attention to the gap between the formalised representations of organisational processes embedded in supplier offerings and the diverse circumstances of the user organisation and its complex, heterogeneous and difficult to formalise practices. CSCW has established without doubt that workplace information technology – even for instances of the same technology – have different effects depending on the organisational contexts in which they are implemented. These accounts have principally emphasised the importance of local action and contingency. In so doing they have drawn attention to the need for local discretion by user-organisation members to repair the deficiencies of computer-based systems which remain generic in comparison to the intricacy of organisational practice. As a result, many writers have problematised the claimed effectiveness of standardised (e.g. packaged) supplier offerings, stressing instead the need for extensive customisation of computer-based systems to get them to match specific organisational practices. Some have even carried this argument further, to insist that information systems must be built around the unique exigencies of particular organisations (Hartswood et al. 2002).

However there has been increasing signs that new kinds of issues and problems are beginning to emerge. In this paper we have argued the need for CSCW to take account of the ways in which information systems at work have changed over the last 20 years – a period in which the systems environment (ecosystem?) has become widely populated by an array of increasingly integrated intra-organisational and inter-organisational systems that we have referred to as Information Infrastructures. The fact we have been forced to articulate this in 2011 as a programmatic statement suggests that CSCW needs to have a more *prospective* viewpoint – and should look forward to current and emerging developments in technology and work. Developments that the CSCW agenda needs to take on board over the coming decade(s) may include (some of which we are happy to note are included in this jubilee issue of the JCSCW):

- New models for provision of compute services – Software as a Service (Saas) and 'cloud computing' - which potentially alter the relationship between the developer and user organisation as well as the scope for local customisation and adaptation;
- Web 2.0 based approaches and Social CRM like systems which make it easy for 'users' with limited computing skills to share information across multiple sites;
- Ubiquitous and ambient computing: networking of devices and systems that generate huge volumes of information; the application of knowledge management and modelling techniques to make this deluge of information more manageable;
- Ideas about 'social computing' that integrates several of these trends into a longer term vision of hybrid-human computer information system – with particular emphasis on the emergence of new forms of work;
- Establishment of platforms for ecosystems/ecologies inspired by Apple's App store/iPhone or iPod/iTunes example that seek to cultivate communities of external developers - simultaneously tying in - to add value and visibility to the platform.

From our literature review in Section Two it is evident that there exist a few CSCW contributions drawing on an II perspective. It would be thus too crude to simply criticise CSCW for not relating to II as such. This would not be fair. However it is true that the bulk of these contributions employ II in a fairly modest manner, typically as a convenient vocabulary providing useful concepts that subsequently are 'labelled' to selected empirical events and episodes. What is lacking is a more ambitious agenda using II to draw out stronger and more compelling implications of a theoretical, methodological and practical nature. We believe this to be the proper challenge for a renewed CSCW agenda.

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